Further notes on the natural history and artificial propagation of the diamond back terrapin

FURTHER NOTES ON THE NATURAL HISTORY AND ARTIFICIAL PROPAGATION OF THE DIAMOND-BACK TERRAPIN

By R. L. Barney

From BULLETIN OF THE BUREAU OF FISHERIES, Volume XXXVIII, 1921–22

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By R. L. BARNEY,

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CONTENTS.

INTRODUCTION.

There appears to have been sufficient progress made in the experimental work on the artificial propagation of the diamond-back terrapin, *Malaclemmys centrata*, at the United States Fisheries Biological Station, Beaufort, N. C., since 1915 to warrant the drawing up of a report covering such information on this subject as has been collected to date and has remained unpublished. In Economic Circular No. 5, revised, of the U. S. Bureau of Fisheries,[1] the results of observations up to and including 1915 are cited with methods outlined for construction of pens, selection of brood stock, care of eggs, young, and adults, and some notes on the growth of the terrapins. Much information has been collected since that time by continuing observations on many of the same terrapins considered in the 1917 report and also through further studies with different purposes begun in more recent years.

[1] Hay, W. P.: Artificial Propagation of the Diamond-Back Terrapin. Economic Circular No. 5, revised. U. S. Bureau of Fisheries, Washington, 1917.

The terrapin propagation study has been directed since its beginning by several investigators. Originally Dr. R. E. Coker gave his attention to its possibilities and prepared a report of his results for the North Carolina Geological and Economic Survey.[2] At the same time Prof. W. P. Hay began similar investigations in Chesapeake Bay. In 1909 these were transferred to Beaufort, where Dr. Hay took charge of the experimental work and continued giving it his direction from 1909 to 1915. During this time H. D. Aller planned and carried out the feeding of yearling terrapins during the winter in a warmed nursery house. Lewis Radcliffe relieved Mr. Aller in 1912 and was later followed by S. F. Hildebrand. Some of the material herewith discussed is from experiments begun by the two last-named investigators, but left unfinished because of their removals from Beaufort. The present paper is based on the unorganized notes of each of the above-mentioned investigators and also on the systematic observations carried on under their supervision by Charles Hatsel, the terrapin culturist stationed at Beaufort, N. C., since the experimental work was begun. The large share of credit for the continuity and the accuracy of the observations of the entire experimental terrapin propagation project is due Mr. Hatsel for his exceptionally careful, energetic, and faithful work. The writer has had the direction of the experiments since the fall of 1919. B. J. Anson has assisted in organizing and tabulating the data discussed in this paper and J. B. Southall has prepared the graphs.

BROOD STOCKS OF THE EXPERIMENTAL FARM.

The terrapins of the original brood stock, which are either the parents or grandparents of all the Carolina terrapins that are held in captivity and under observation at the Beaufort station, were purchased in two lots, the so-called "original lot of North Carolina breeders" and the "second lot of North Carolina breeders." To these was added later, but kept separate, a number of adult Texas terrapins as brood stock. The production in eggs and young throughout the years of captivity of these terrapins is herewith tabulated (Table 1) and shown in graphic form (fig. 76).

TABLE 1.—RECORDS OF BREEDING STOCKS OF TERRAPINS IN CAPTIVITY AT BEAUFORT, N. C.

Stock and year.	Males.	Females.	Eggs.		Young.		Per cent eggs hatched.
			Number.	Rate per female.	Number.	Rate per female.	
Original stock:							
1909	23	44	12	(?)	12	(?)	(?)
1910	23	44	288+	6.5+	288	6.5	(?)
1911	[a] 18	43	598+	13.9+	598	13.9	(?)
1912	18	43	688	16.0	538	12.5	78.1
1913	18	43	732	17.0	610	14.1	88.3
1914	18	39	736	18.8	594	15.2	80.7
1915	18	39	922	23.6	836	21.4	90.6
1916	18	39	921	23.6	813	20.8	88.2
1917	18	39	722	18.5	639	16.3	88.5
1918	18	39	[b] 757	[b] 19.4	[b] 675	[b] 17.3	[b] 89.1
1919	[a] 23	39	[b] 834	[b] 21.3	[b] 757	[b] 19.4	[b] 90.7

[a] Five males taken from this lot for experimental purposes in 1911 were returned to it in 1919.
[b] Estimated.

[2] Coker, R. E.: The Cultivation of the Diamond-Back Terrapin. Bulletin No. 14, the North Carolina Geological Survey. Raleigh, 1906.

TABLE 1.—RECORDS OF BREEDING STOCKS OF TERRAPIN IN CAPTIVITY AT BEAUFORT, N. C.—Con.

Stock and year.	Males.	Females.	Eggs.		Young.		Per cent eggs hatched.
			Number.	Rate per female.	Number.	Rate per female.	
Second stock:							
1911	45	70	.....	.....	.....	.....	.....
1912	45	70	649	9.0	583	8.3	89.8
1913	45	70	673	9.4	606	8.6	90.0
1914	45	70	745	10.4	724	10.2	97.1
1915	45	70	958	13.4	876	12.5	91.3
1916	29	64	871	13.6	783	12.2	89.8
1917	29	63	[a] 973	[a] 15.4	805	12.7	[b] 82.7
1918	28	63	[a] 731	[a] 11.5	[a] 670	[a] 10.6	[b] 93.0
1919	27	50	[a] 773	[a] 15.4	[a] 702	[a] 14.0	[b] 90.8
1920	[b] 50	89	1,172	[c] 13.1	1,133	[c] 12.7	96.6
Texas stock:							
1912	[d] 32	34	127	3.7	101	2.6	79.5
1913	[d] 29	34	292	8.5	281	8.2	96.2
1914	[d] 29	34	412	12.1	376	11.0	91.2
1915	[d] 29	34	399	11.7	366	10.7	91.7
1916	[d] 12	25	421	16.8	383	15.3	90.9
1917	[d] 12	25	497	19.8	439	17.5	88.3
1918	[d] 12	25	[e]	[e]	[e]	[e]	[e]
1919	5	11	270	24.5	247	22.4	91.4
1920	5	11	138	[c] 12.5	134	[c] 12.1	97.0

[a] Estimated.
[b] The 1920 record represents the combined production of the original and the second brood stocks. The penning together of individuals of both stocks made it impossible to ascertain the production of either stock.
[c] Decrease in production probably due to destruction of eggs by rats.
[d] This record for males includes five Carolina original stock males used in hybridization studies.
[e] Records for production not obtained on account of storm which destroyed egg beds and washed many small and adult terrapins from their inclosures.

ORIGINAL CAROLINA BROOD STOCK.

Considering the original or first lot of breeders it will be noted that highest egg production occurred in 1915 and that since then the egg rate per female, with exactly the same number of females laying, has diminished by from three to five eggs. The percentage hatched has varied but slightly. This, however, would be reasonably expected with the same number of males on hand and the number of eggs to be fertilized somewhat less. In view of the fact that egg production has fallen off since the 1916 production and remained under that high mark now for four years through 1920, it seems probable that the period of maximum egg production in this brood has passed. However, the slight increase during 1918 and 1919 perhaps means that the brood may still reach greater egg production than its maximum egg record of 1915. Still beneath the maximum mark, it may also indicate that certain females are about to reach maximum production while others have passed this point. The heavy falling off in recorded egg production in 1920 (see figures for 1920 under second stock in Table 1) was due to the depredations of rats which dug up many nests and destroyed hundreds of eggs before control methods were effective. The 1920 figures, therefore, do not represent the possible egg production and hatch, for the record of eggs laid would doubtless have been very much higher had it not been for the destruction caused by the rats.

The average size of the females of this lot in 1911 was 154 mm.[3] Considering what is known of the history of some of the individuals of this lot since 1902, their size then and their growth since, it appears probable that at the time of their measurement in 1911 they averaged close to 20 years of age. The estimated age of these terrapins is

[3] Approximated from measurements recorded in inches.

arrived at from a knowledge of their size at the time of their purchase and of the number of years during which they have been captive in the experimental pens. They were all adults at the time of their purchase, and the approximation of their age must be quite accurate. From the knowledge that it takes at least much longer than nine years for hibernating terrapins to reach an average length of 142 mm. (see Table 3) and that after the length 142 mm. is reached the average annual growth increment is not more than 1.5 mm., it appears reasonable that the age of the terrapins of this brood was at least 18 years in 1911 (the year of measurement).

	Years.
To reach average length of 142 mm	9
To grow from 142 to 154 mm. (the 1911 average length)	9
From 1911 to 1921	10
Total average age in 1921	28

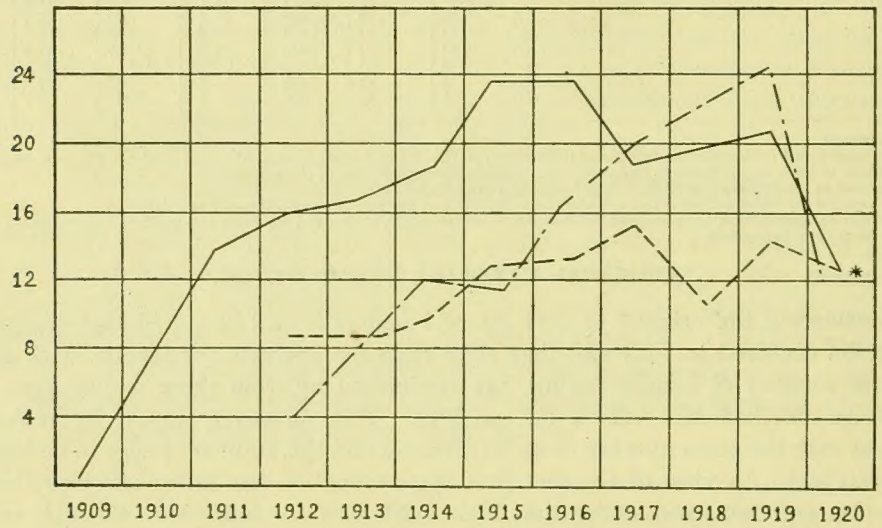

FIG. 76.—Egg production per female in original and second Carolina and Texas brood stocks. ——, Original Carolina brood stock; — — — —, second Carolina brood stock; —·—·—·—·, Texas brood stock; * combined egg production per female of original and second Carolina brood stocks. Marked decrease in egg production probably due to destruction of eggs by rats.

Inasmuch as maximum recorded egg production for this lot occurred in 1915, we may presume, then, that maximum egg production occurs about the twenty-fifth year of a terrapin's life. The actual maximum production of young, however, would, of course, depend on the presence of sufficient males among the breeding stock.

SECOND CAROLINA BROOD STOCK.

The second lot of North Carolina breeders, with average measurement of 141 mm.[4] in 1911 and probable average age of 9 years, has shown, with the exception of the years 1918 and 1920, a general increase in egg production since the beginning of its laying. The 1918 record showed a dropping off in egg production of 2.1 eggs per female. The reason for this decrease is problematical, but the exceptionally severe winter of 1917–18 and the following late spring, with its resulting longer hibernation period and its retard-

[4] Approximated from measurements recorded in inches.

ing influence on normal spring feeding and growth in the terrapins, may possibly be the causes of the decreased productiveness, though a similar decrease is not found in the egg production of the original brood stock. The 1920 decrease shown in Table 1 is due in part to the destructiveness of the rats above referred to and probably also to a very late spring, the first eggs being laid on May 17, a rather late date. Many of the brood terrapins, however, did not lay their first eggs of the season until the middle of June, more than a month after the usual first egg-laying date. In 1917 certain of the females of the second lot of breeders were set aside for experimental purposes, and this had a tendency toward diminishing the actual number of young produced, while the experiments yielded information which is of value from other aspects and will be discussed later. Because of this experimental work the figures for "young" in the table are estimates and are included only tentatively in the 1918 and 1919 records. The mixing of part of the first lot with the entire second lot of breeders in 1918 and 1919 made it necessary also to estimate the number of eggs laid by both these lots, and these records have been so noted.

The estimation was possible in view of the fact that a considerable proportion of the original brood stock was not mixed with the second brood stock. The method followed to obtain the estimated records was this. One lot of the original brood stock (lot A) was held in a separate pen during the year, and from the egg and young production of this lot was computed an average egg and young production for the entire original brood stock. From this computation it was possible, then, to figure the production of those terrapins (lot B) of the original brood stock which had been penned with the second brood stock. The egg and young production of the entire second brood stock (lot C) was ascertained by subtracting the egg and young production of lot B from the total egg and young production of lots B and C combined, lot B plus lot C representing the mixed lots of brood stock.

In 1920 the terrapins of the first and second lots of breeders were so mixed that it was impossible to estimate at all accurately the egg production of either lot, and for this reason the egg production and hatch of these broods for 1920 are combined. The combined egg and young production record, though lower than that of either lot in the preceding year, is not significant, however, because of the heavy egg destruction caused by rats.

TEXAS BROOD STOCK.

The Texas brood stock, with average length in the spring of 1920 of 177 mm.[5] and probable age of 30 years, has shown an increasing productiveness annually since its first laying in confinement until 1920, when doubtless, as above, the decrease in the egg and young production record was due to destruction of eggs by rats. In 1919 from 11 adult females of this stock which had been used in hybrid studies with Carolina males there were obtained 270 eggs, or 24.5 eggs per female. In 1916 all but 12 of the Texas terrapins were returned to Texas. The 12 that remained were the finest and largest females of the original Texas lot, and the exceptional egg production of the 11 mentioned above may be due to this fact. It is understood that when the entire Texas brood stock was at Beaufort the average number of eggs produced per female was lower than for either of the Carolina lots.

[5] Approximated from measurements recorded in inches.

It is noteworthy in this connection that this maximum production for the Texas stock is greater than that of the Carolina breeders. The maximum records of the two stocks are as follows: Carolina, egg rate, 23.6; young rate, 21.4. Texas, egg rate, 24.5; young rate, 22.4.

The excessively cold winter of 1917–18, which apparently slowed down output among the second brood stock of Carolina terrapins, did not effect any retardation in the productiveness of the Texas stock. The heavy decrease in recorded productiveness of this brood stock in 1920 is due to destruction of eggs by rats, as in the case of the first and second lots of Carolina breeders.

RATIO OF SEXES AND FERTILITY.

The number of males in a given stock of brood terrapins in each of these experimental lots has been about one-third to one-half the number of females present. There appears to be a negligible difference in the rate of young hatched per female in the different broods with differing percentages of males present. A normal hatch appears to be about 90 per cent of the eggs laid, no matter how great a number of males may have been present. It is needless to say that scarcity of males would, of course, increase the number of infertile eggs laid. This percentage of infertile eggs is much larger at the beginning of the laying period (fig. 79) of the terrapins and at the beginning of captivity (Table 1).

The cause of the high infertile egg rate among terrapins which have laid for the first time under our observation and have been penned with male terrapins of exactly their age throughout their lives may be found in the fact that possibly the males do not reach sexual maturity as early as the females. This is indicated in a study of certain lots of terrapins experimented with during 1919. Seventy-eight female terrapins of the 1914 brood which had never laid fertile eggs, due to the fact that males had never been penned with them, were separated into two equal lots which were kept in separate pens. With one lot of 39 females were placed 3 males of the original brood stock at least 25 years old; with the other lot were placed three 5-year-old males of the 1914 brood. This division of the lot and introduction of males occurred on the same day in early spring, so that there might be plenty of opportunity for fertilization to occur before the egg-laying period arrived. The production was as follows:

	Females.	Males.	Age of of males (years).	Eggs laid.	Eggs hatched.	Per cent fertile eggs.	Per cent infertile eggs.
Pen 9	39	3	5	245	54	22.0	78.0
Pen 19	39	3	25	187	152	81.2	18.8

It is suggested from these data that males of 5 years are less potent than much older ones and that maximum fertility may not be expected where young males, just reaching sexual maturity, are used.

In reviewing the entire matter of the most desirable numerical relation of males to females in this species, it should be pointed out that mating among terrapins is promiscuous. Copulation in one year may mean the production of fertile eggs for more than that year alone. To cite a case under our observation, in 1914, 10 females of the second lot of Carolina breeders which had been producing young were set aside in a separate pen without males. With no further association with males, these terrapins

laid fertile eggs each subsequent year until and including 1918. The record of egg production and hatch of these 10 terrapins through 1918 is as follows:

	Eggs.	Young.	Per cent infertile eggs.		Eggs.	Young.	Per cent infertile eggs.
1915	129	128	0.7	1917	130	39	70.0
1916	116	102	12.0	1918	108	4	96.2

In the spring of 1919, 5 males were introduced into this lot, and the fall production was 137 young from 146 eggs. From this experiment it appears that female terrapins may retain live spermatozoa in a healthy condition after a single copulation as long as four years, and under such conditions some eggs laid even in the fourth year may be fertile. It is apparent also that fertilization may occur immediately after copulation.

In further consideration of the proper ratio of sexes for maximum fertility we have the records of several domestic broods (Table 2) which, it happens, have contained fixed ratios of males per 100 females throughout their existence. This set of observations includes lots in which the males number 5, 9, 12, 24, 32, and 50 per 100 females, and the records give some suggestion of what may possibly be the most desirable ratio of males to females to produce maximum fertility.

TABLE 2.—SEX RATIO AND FERTILITY OF THE DIAMOND-BACK TERRAPIN IN CAPTIVITY.

Egg-laying year.	Males.	Females.	Males per 100 females.	Eggs laid.	Per cent fertility.	Egg-laying year.	Males.	Females.	Males per 100 females.	Eggs laid.	Per cent fertility.
1909 hibernated brood						1910 winter-fed brood:					
First	8	4	200	96	77.8	First	10	140	8	12	100.0
Second	8	4	200	118	63.5	Second	10	107	9	348	83.3
Third	2	4	50	98	73.4	Third	10	107	9	572	78.6
Fourth	2	4	50	119	95.7	Fourth	10	104	9	606	90.5
Fifth	2	4	50	138	94.7	Fifth	9	103	8	952	75.4
Sixth	2	4	50	140	89.2	Sixth	9	103	8	298	45.9
1910 hibernated brood:						1911 winter-fed brood:					
First	5	89	5	38	97.4	First	10	82	12	8	100.0
Second	5	89	5	200	82.4	Second	10	82	12	7	0.0
Third	5	89	5	452	93.2	Third	10	82	12	470	94.1
Fourth	5	89	5	640	75.0	Fourth	10	82	12	682	93.5
Fifth	5	89	5	421	61.2	Fifth	10	82	12	983	84.6
1910 selected brood:						Sixth	10	82	12	621	88.8
First	8	25	32	27	81.5	1912 winter-fed brood:					
Second	8	25	32	418	74.0	First	18	43	24	127	91.4
Third	8	25	32	529	91.2	Second	18	43	24	188	85.1
Fourth	8	25	32	526	95.5						
Fifth	8	25	32	678	91.5						
Sixth	8	25	32	407	95.7						

In viewing the records of these broods it is necessary to bear in mind that maximum fertility does not occur in the first year of laying in any brood unless there happens to be laid only a very few eggs which may have, by chance, become fertilized. Accepting 90 per cent as normal fertility, it will be noticed that this per cent of fertility was reached in the 1910 hibernating brood in the third year of laying, and that this brood contained only 5 males per 100 females. However, in the following year, when there were about 200 more eggs laid, the per cent of fertility dropped to 75. The fifth year, though showing a decrease in fecundity in the terrapins, shows another considerable lowering of percentage fertility. A similar drop in the per cent of fertility is also found in the fifth and sixth years of laying of the 1910 winter-fed brood after it had reached at least 90 per cent fertility in previous years. It was accompanied in the fifth year by an

increase of 346 eggs to be fertilized. The 1911 winter-fed brood in its fifth year of laying also showed a decreased fertility of approximately 9 per cent, with an increase of 301 in number of eggs to be fertilized. Even with a smaller number of eggs by 362 to fertilize in its sixth laying year there was only a 4.2 per cent increased fertility, 12 males being present throughout the observations.

To be compared with these records there are the 1910 selected brood and the 1912 winter-fed brood. These contained, respectively, 32 and 24 males per 100 females. The lot with 32 males per 100 females has yielded better than 90 per cent fertility now for the past four years, even though the egg production with the exception of the last year has increased yearly during this period. This is an especially good record in view of the fact that the egg rate in this lot in 1919 averaged 27.1 per female. The 1912 winter-fed brood, with 24 males per 100 females, has laid but twice, and it is needless to say the record of these first two years may not be indicative of the future record of this group. However, the egg production was very large for the first laying year, and the percentage of fertility of the eggs in this case may be of considerable comparative value. This record is the highest of our observations for percentage of fertility in the first year where there has been substantial egg production. It will be noted, however, that with an increase of egg production in the second year the percentage of fertility declined to 85.1 per cent.

The 1909 brood, in which there are half as many males as females, has given during the past three years a high record. There is no doubt that there are more than enough males in this lot, since the 1910 select brood has a record equally as good in percentage of fertility and contains only 32 males per 100 females.

From our table and this discussion it seems warranted to conclude that after the brood has established a substantial egg-laying record a 90 per cent fertility may be obtained with from 24 to 32 males per 100 females. The record of the 1911 hibernated brood is good with only 12 males per 100 females. This record may be influenced, however, by the fact that appreciable egg laying in this brood was relatively late, coming in the ninth year, and thus much more time for copulation was available with but very slight utilization of the spermatozoa.

GROWTH.

Many data at hand concerning feeding and growth and their bearing on the development and functioning of the sexual organs of the terrapin are of value to the commercial terrapin culturist. The several annual broods, the offspring of the original and second lots of breeders, have had chosen from them certain numbers of individuals which have received varying treatments, the results of which can be compared to advantage.

The effect of hibernation on the growth of the small, newly hatched terrapin is considerably different from that of winter feeding in a warmed nursery house. Whereas the hibernated terrapin grows none during the winter, the fed terrapins may make considerable growth. The food used and the temperature at which the terrapins are kept appear to be the factors most influencing growth in the nursery house. The heating plant employed at Beaufort is merely a large coal-burning sheet-iron stove. The radiation from this stove causes the water of those boxes closest to the stove to remain at high temperature throughout the day and night, while those farther away are not so thoroughly and continually kept at as high a temperature. These feeding boxes closest to the stove always contain the largest terrapins in the spring, while those at the greatest

distance from the stove contain the smallest. This indicates the desirability of having a heating system which radiates its warmth equally and in constant and considerable quantity. To the commercial culturist a heating system of this kind is of prime necessity. The effect of winter feeding other than in its bearing on actual growth—that is, in causing earlier arrival at sexual maturity—will be indicated in certain of the annual brood studies. This is another valuable consideration for the commercial grower of terrapins.

What growth may be expected of winter-fed terrapins, compared with those that are allowed to hibernate, is well suggested in the records of the 1910 and 1911 broods, lots of which received these treatments, respectively. The fed lots at any age are generally about 1 year's growth in advance of the hibernating lots, and in some cases much more. This difference in growth in 2 and 3 year old terrapins is from about 10 to 20 mm. The difference between the average lengths of the lots diminishes as they pass the fourth year. From this time on the variation averages about 10 mm. and remains thus constant through the ninth year, if not longer (Table 3, fig. 77).

TABLE 3.—GROWTH OF WINTER-FED VERSUS HIBERNATED TERRAPINS.

Age in years.	Season of measurement.	1910 and 1911 broods combined.					
		Winter-fed.			Hibernated.		
		Number.	Measurement in millimeters.		Number.	Measurement in millimeters.	
			Total.	Average.		Total.	Average.
1	Spring	97	[a] 3,006	30.9	98	[a] 2,738	27.9
	Fall	95	4,467	47.0	89	3,833	43.0
2	Spring	125	7,067	56.5	190	7,980	42.0
	Fall	182	14,392	79.0	182	10,976	60.3
3	Do	183	16,667	89.9			
4	Spring				175	15,807	90.3
	Fall	81	9,315	115.0	78	8,260	105.8
5	Do	209	26,556	127.0	168	19,486	115.9
6	Do	132	17,277	130.8	167	20,560	123.1
7	Do				156	20,347	130.4
8	Do	201	29,692	142.7	167	22,757	136.2
9	Do	126	17,984	142.7	89	12,147	136.4

[a] Measurement of plastrons.

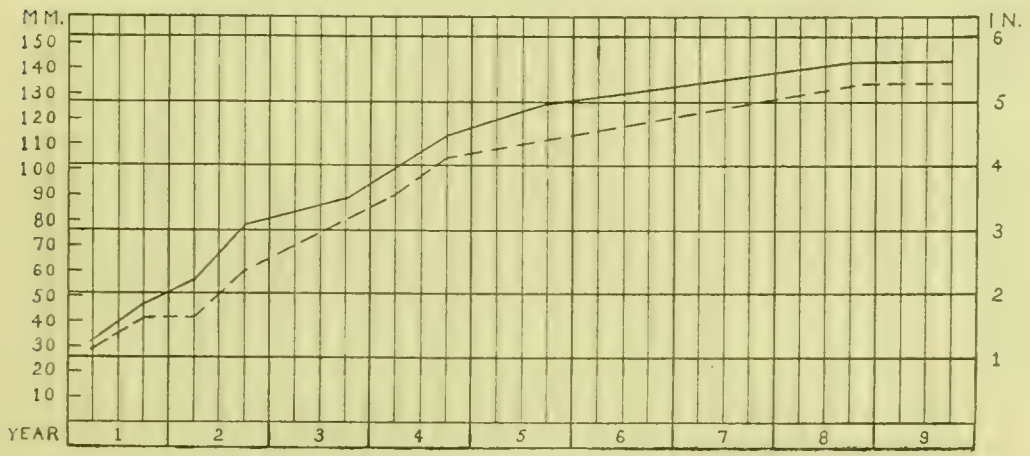

FIG. 77.—Average growth of winter-fed and hibernated terrapins. Curves based on combined records of growth of winter-fed and hibernated lots of the 1910 and 1911 broods. ————, Winter-fed; — — — — — — — hibernated.

ATTAINMENT OF SALABLE SIZE.

The relation of age and growth to salability is of importance to the prospective terrapin farmer, and for this purpose a table has been prepared showing the number and per cent of terrapins of the 1910 winter-fed and hibernating lots reaching the 5 and 6 inch lengths at given ages (Table 4). The rate of growth of the terrapins in captivity is heavily retarded between the 5 and 6 inch lengths.

TABLE 4.—ATTAINMENT OF MARKETABLE SIZE BY FEMALES OF 1910 BROOD.

Age in years.	Six inches.				Five inches.			
	Winter-fed.		Hibernated.		Winter-fed.		Hibernated.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
4	.....	.....	.....	.....	32 in 81	39.5	.....	.....
5	2 in 127	1.5	.....	.....	67 in 127	52.7	14 in 90	15.5
6	8 in 133	6.0	.....	.....	90 in 133	60.2	34 in 89	38.2
7	.....	[a] 10.0	1 in 78	1.2	.....	[a] 71.0	45 in 78	57.6
8	20 in 129	15.5	2 in 89	2.2	108 in 129	83.7	75 in 89	84.2
9	25 in 129	20.3	4 in 89	4.4	123 in 129	95.3	85 in 89	93.2

[a] Estimated.

It will be noted that in the fifth year only 1.5 per cent of the winter-fed brood had reached the 6-inch length. In the sixth year 6 per cent of the brood had reached that length. The figures in the table appear small when a mere hundred terrapins are considered. To multiply them several times, however, changes them to the exact meaning they would have for the terrapin farmer—not merely to multiply them by the number of hundreds in the one brood alone, but to multiply them also by the number of broods which contain individuals that are reaching the 6-inch mark.

In the fifth year it appears that 52.7 per cent of the terrapins of the winter-fed brood has reached the 5-inch mark. Although the price paid for 5-inch terrapins in the market is not nearly so much as that for 6-inch, it is evident that selling when the 5-inch mark is reached may have its value from a commercial viewpoint. It means a quicker turning over of the money invested and possibly a better business proposition when large numbers of terrapins are considered. For example, a terrapin farmer may rear from the eggs possibly 15,000 or more terrapins per year. Eliminate one-half (a much too large percentage) for death rate during the five years. Now, in the fifth year, 3,750 terrapins will have reached the 5-inch mark. This is approximately 300 dozen, which, sold at $20 per dozen, bring $6,000. The market for 6-inch terrapins would have to be especially good to make the two or three years' extra keeping of them pay. However, the market for 6-inch terrapins generally pays double the amount paid for 5-inch terrapins, and there is the possibility that the raising of terrapins to the 6-inch length is the more desirable business proposition, especially when it is remembered that there will be an increasing number of broods producing 6-inch terrapins after the enterprise has been carried for a few years, not to mention the increasing young production.

CULLING.

Each brood of newly born terrapins contains a great many which, when held in a warm nursery house, will not eat, or, if they do, do not make any growth. They serve only to bring down to a lower figure the average annual growth increment of the lot.

If, however, one selects the largest grown three-quarters of each lot, the average growth increment for 1-year-olds is much increased. To indicate this point, a concrete example will best serve the purpose. There were 1,004 terrapins of the 1916 hatch placed in the nursery house in November, 1916. During the following winter 500 or more of the same brood were allowed to hibernate, while the larger lot was fed. In May, 1917, the average length of the 1,004 was 39.2 mm. The best grown three-quarters, or 780 terrapins, had an average length of 42.9 mm. The largest 200 terrapins of this lot averaged 54.7 mm. in length. To be compared with this lot there was still the unchanged fall average measurement of the hibernated terrapins, 28.1 mm.

From this discussion it appears that it would be economical to cull the young, poorly grown terrapins, either to force-feed them, liberate them because of their relative costliness in handling, or to sell them as soon as possible after they reach the 5-inch length in order that all the fast-growing characteristics of the brood stock may remain unmixed and protected against contamination with slow-growing individuals.

Present knowledge of the relative growths of first-year "runts" and first-year "selects," however, indicates that discarding or too strict culling of "runts" at the end of the first year is not entirely economical, since it has been learned that terrapins of poor first-year growth often reach in the fourth or fifth year equal length with their "select" brothers. It would doubtless be profitable to destroy very early any yearlings that show symptoms of disease unless effective remedial and prophylactic treatments are available.

WINTER FEEDING.

In view of the fact that in some locations favorable for terrapin culture fresh food may not always be available or may cost excessively, experiments have been carried on to learn the relative value of fresh and salt food in its assimilability and its growth-producing value. For this purpose one lot of newly hatched terrapins with an average length of 28 mm., 662 in number, was fed oysters, while another lot of the same age and average length, 613 in number, was fed salt fish. It appears from the following tabulation that the fresh-fed terrapins thrive much better than the salt fed:

Treatment.	Number of terrapins.	Average length, September, 1916.	May, 1917.			
			Average length.	Maximum length.	35 millimeters or more.	Average length of 100 best.
		Mm.	*Mm.*	*Mm.*	*No.*	*Mm.*
Salt-fed	613	28.0	29.9	40.0	34	34.2
Fresh-fed	662	28.0	33.8	51.0	228	42.7

The maximum length of any terrapin under our observation kept through one winter and until the following May in the nursery house is 81 mm.[6] The greatest length of a winter-fed terrapin at approximately 2 years of age (measured in September) is 104 mm.,[6] or slightly more than 4 inches. The offspring of domestic stock appear to do better in captivity than those of "wild" stock (fig. 78). From measurements

[6] These measurements are taken on the lower shell, following the commercial method of measuring a terrapin: 81 mm.=3¼ inches; 104 mm.=4⅛ inches.

taken in the autumns of 1919 and 1920 the following information on this point was brought to light:

Offspring of—	Number.	Age in years.	Treatment.	October, 1919.		Average length in millimeters, October, 1920.
				Average length in millimeters.	Maximum length in millimeters.	
"Wild" stock	95	3	Fed one winter	65.3	87	66.8
"Domestic" stock	99	3	.....do	74.4	116	76.5

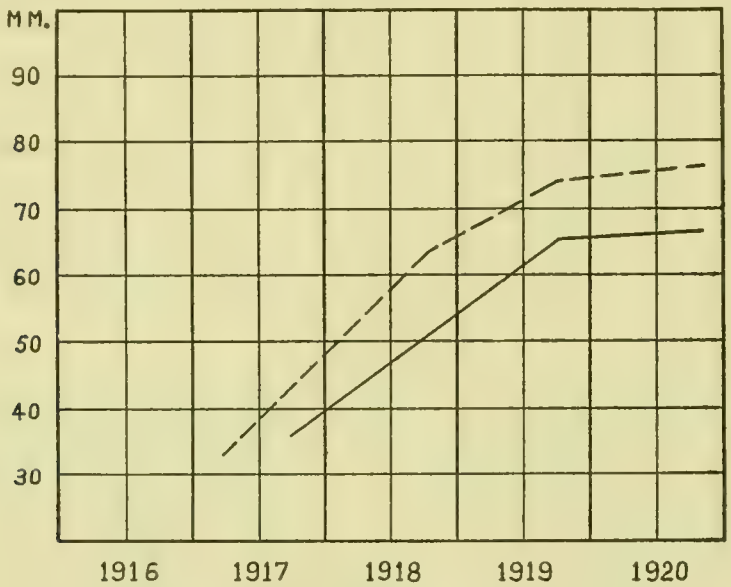

FIG. 78.—Growth of 1916 offspring of domestic and wild parentage. Each lot was fed one winter and selected for large size in the fall of 1917. — — —, Offspring of 1909 domestic stock; ————, offspring of original Carolina wild brood stock.

SPACE REQUIREMENT.

The 1917 brood had two lots of 100 each chosen from it in 1919. One of these lots, with average measurement of 52.5 mm., was placed in a large so-called fish pool which measured 38 by 24 feet. The other lot with average measurement of 60.1 mm. was placed in a small pen with dimensions of 29 by 12 feet. Observations on the growth of the two lots have been as follows:

Treatment.	Square feet per terrapin.	Number of terrapins.	Average length in millimeters.		Increased length in millimeters, May to October, 1919.	Average length in millimeters, Oct. 5, 1920.	Increased length in millimeters, October, 1919, to October, 1920.
			May, 1919.	Oct. 23, 1919.			
Closely confined	3.6	100	60.1	66.6	6.5	70.3	3.7
Wide range	9.3	100	52.5	60.9	8.4	72.2	11.3

A conclusive statement of space requirement or of the value of extensive running ground is not warranted from this single set of observations. It is of significance, however, that the greater growth has occurred in two successive years in the larger pool. This may have been due, nevertheless, as much to the fact that the terrapins were smaller in this pen than in the "close-confinement" pen and may have just reached or were in a stage of rapid growth, whereas the other group may have passed that same period. That plenty of space has a tendency to increase fecundity in the terrapin is suggested by the 1909 brood. These terrapins, held in a pen 32 by 5 feet for six years, have had a very large average yearly egg production per female. This pen provides each terrapin with approximately 26.6 square feet of ground. The exceptionally high laying record of these terrapins may be due, in part, to the large space and uncrowded condition of their pen. Their size, of course, is large, but abundant space may be a contributing factor in causing increased productiveness.

1909 BROOD.

This brood, the first terrapins hatched in captivity in the Beaufort pens considered in this paper, consisted of 12 individuals—8 males and 4 females. Several of the males

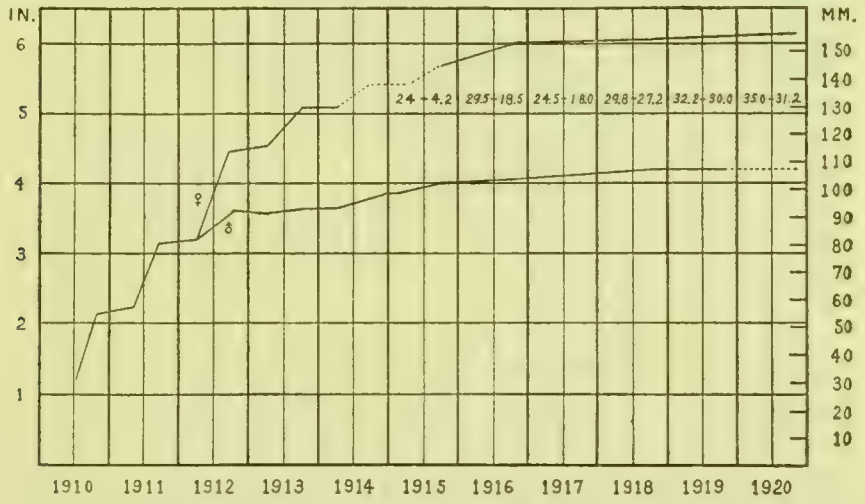

FIG. 79.—Growth of 1909 brood of original Carolina brood stock. Egg production and hatch per female per year expressed, respectively, by figures on the curve. This brood has always had but four females. ·····, Estimated.

of this lot have been used in other experiments, and since 1915 there have been only 2 males with the 4 females under observation. They have been kept during this time in a small pen which, however, is large enough to support many more terrapins than these 6. This 1909 lot has hibernated each winter since its birth and shows what is probably a normal growth and development for terrapins held in captivity. The first eggs from the females of this brood were laid in 1915 (fig. 79) when the terrapins were 6 years old. The egg rate per female in that season was 24. Yearly since then there has been an increase, until in 1919 the egg rate reached 32.2 per female. This 1919 egg production was accompanied by a hatch of 30 young per female and represented at that time the best record observed at Beaufort for average egg production and hatch. In 1920, how-

ever, the brood surpassed its best record again by laying 140 eggs, of which 125 hatched, giving an average egg record of 35 per female and an average hatch of 31.2 young per female. There were 16 nests found in 1919 and 19 in 1920, indicating quite conclusively that all females of the 1909 brood laid at least four times and that three of them laid five times in 1920. Growth after the seventh year is small, but it is attended by increasing fecundity. The cause of the high percentage of infertile eggs in the first year of laying of this brood may be due to the fact that the males of the brood were not mature. However, the following year the larger part of the eggs by far was fertile.

1910 BROOD.

Two lots of the 1910 brood were set apart in the fall of 1910, one fed the first winter, the other allowed to hibernate. A comparison of the average growth of these two lots indicates that the first lot, winter-fed, by average measurement, arrived at the 5-inch

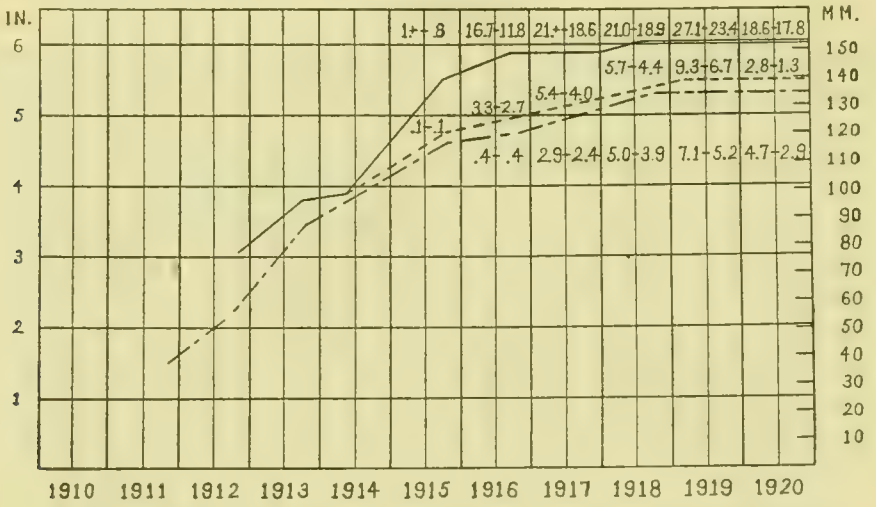

FIG. 80.—Growth of 1910 brood of original Carolina brood stock. Egg production and hatch per female per year expressed, respectively, by figures on the curves. ————, Fed two winters and selected for large size in the spring of 1914; — — — —, fed one winter; —·—·—, hibernated.

mark and to egg-laying one year before those that hibernated, and also that the egg-laying began at a higher rate and continued higher than that of the hibernated group (fig. 80). In early spring (1915) 8 males and 25 females were selected for size from the fed lot and kept in a separate inclosure. Their egg production in the second year of their laying was 16.7 per female, a much greater productiveness than was made either by the ordinary lot of fed terrapins from which the selected individuals were chosen or by the lot of hibernating terrapins three years later in 1919.

These facts indicate that for the commercial terrapin culturist it would pay more in a series of years to hold the largest and fastest growing stock as breeders rather than to pick here and there for his commercial sales. He could hold such brood stock over a long period of years and feel certain that maximum production would not come before at least 15 or 20 years. He would know, also, that the egg production of his breeders was as large as could be obtained. Thus, each year a certain number of the best grown females of 3 years or older could be chosen to be held as the established brood stock.

The balance could then be used as salable stock whenever their size was great enough to make them marketable. This would tend, then, to the selection by the terrapin farmer of his best producers and fastest growers and in the course of years lead to a race of quick-growing, large-framed, and highly productive terrapins.

1911 BROOD.

The 1911 brood has consisted of two lots of terrapins, one fed two winters and hibernating thereafter, the other hibernating each winter. The average growths of these two groups differ about 12 mm. at any season of any year. The tendency, however, as age increases, is toward a diminishing of this difference in the average growths. The evidence brought to light in the 1910 brood that winter feeding tends toward earlier productiveness is borne out in this brood also. In the fed lot the first egg laying occurred

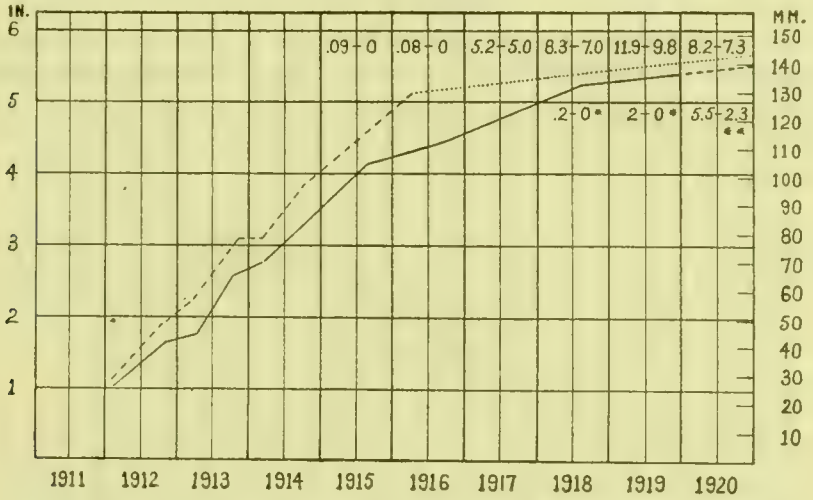

FIG. 81.—Growth of 1911 brood of original Carolina brood stock. Egg production and hatch per female per year expressed, respectively, by figures on the curves. ————, Fed two winters; - - - - - -, hibernated; ·····, estimated; * no males in this lot previous to this year; ** fertility modified by experimentation.

in the fourth year, probably by only one female. Substantial output occurred in the sixth year with an egg rate of 5.2 per female. The first production of the hibernating lot occurred in the seventh year, but this was negligible—0.2 egg per female. The second egg laying in the hibernating stock was likewise small, the rate per female being 2 eggs. This only further points out the desirability of winter feeding. It indicates, also, when the results are compared with the 1910 brood lot which was fed only one winter, the futility and extra cost of feeding terrapins more than one winter. It appears that the 1910 winter-fed brood has shown that egg production and growth from one year's winter feeding is much more desirable than the same from two years' winter feeding when selection is not made of the brood stock.

It may be added in this general connection that winter feeding does not tend toward the development of weaker adults nor necessarily to animals more susceptible to disease. It is true that young terrapins in the nursery house are subject to disease, and there is occasionally considerable mortality from this cause. It apparently kills many of those that would probably die from inherent weakness at best. There are

many terrapins which suffer an attack of the disease in question and again recover their well-being. The subject of mortality among the young terrapins is discussed on page 108.

It is of interest to note in further discussion of feeding two winters and its lack of advantage to the culturist the fact that, from average measurement, the hibernated terrapins reach the 5-inch mark approximately one year and one-half after those fed two winters. Referring again to the 1910 brood, the lot fed one winter reached the 5-inch mark two years before the 1910 hibernating group. It may then, perhaps, be that two winters' feeding may slow down growth rather than hurry development. It will be noted, too, that egg production in the 1910 brood lot fed one winter is negligibly different as regards the year of substantial egg production from that of the 1911 lot fed two winters

1912 BROOD.

The 1912 brood was fed the first winter and allowed to hibernate each winter thereafter. In the spring of 1914 there was made a selection of 100 each of the smallest and

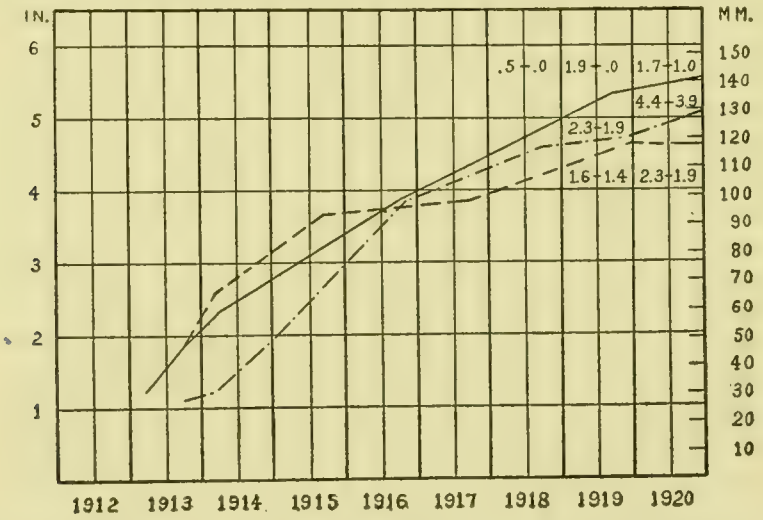

FIG. 82.—Growth of 1912 broods of original Carolina and Texas brood stocks. Egg production and hatch per female per year expressed, respectively, by figures on the curves. ————, Offspring of Texas brood stock, fed one winter; — — — —, offspring of Carolina brood stock, selected from winter-fed lot for large size October 1, 1913; ·—·—·—·, offspring of Carolina brood stock, selected from winter-fed lot as runts October 1, 1913.

largest grown terrapins of the stock. These two lots were kept separately, and their growth and egg production to 1920 have been observed. The lot selected for large size after the first two years did not exhibit as unusual growth as it had in the first winter, while the "runts" after 1915 showed relatively much faster growth. Their average length in 1917 was about 10 mm. greater than the lot which had been chosen originally for its early rapid growth. Both lots produced eggs in the same year (1919) when they were 7 years old. It is of interest to note in this connection that the "runt" group averaged 2.3 eggs per female, while the "selects" averaged 1.6 eggs per female.

It is suggested, then, from this brood stock that selection with a view toward early attainment of salable size or early and increased egg production took place at too

young a stage in the development of the terrapins to be of any advantage to the terrapin culturist. A comparison of this 1912 study in the effect of selection with that of the "selects" of the 1910 brood emphasizes this point. Selection for size occurred in the 1910 brood when the terrapins were 4 years old. The egg production from these "selects" was especially large. In the 1912 lot the egg production is not above normal for either group of terrapins fed one winter and remaining unselected. Selection as early as the second year is premature, since the terrapin at that age has not reached one-half its adult size, and there may be many influences after the second year to retard growth in what then appears as an exceptionally healthy and rapidly growing terrapin.

The Texas brood of 1912, numbering 24 in 1916, 1917, and 1918, and 14 from 1919 to 1921, has shown greater average growth and produced eggs in 1918, a year earlier than the Carolina terrapins of the same age. The possible earlier arrival of the offspring of Texas stock at sexual maturity may be hereditary in character. All the antecedents of this Texas stock were from the marshes of Texas, where the longer growing and laying season with the very limited hibernation period would normally tend toward the occurrence of an earlier maturing animal than would be found in nature in North Carolina. This early maturing characteristic may have become inherent in the Texas stock.

1913 BROOD.

The 1913 brood was originally divided into two lots—one hibernated while the other was fed. Of the fed lot the largest 100 terrapins were selected for further

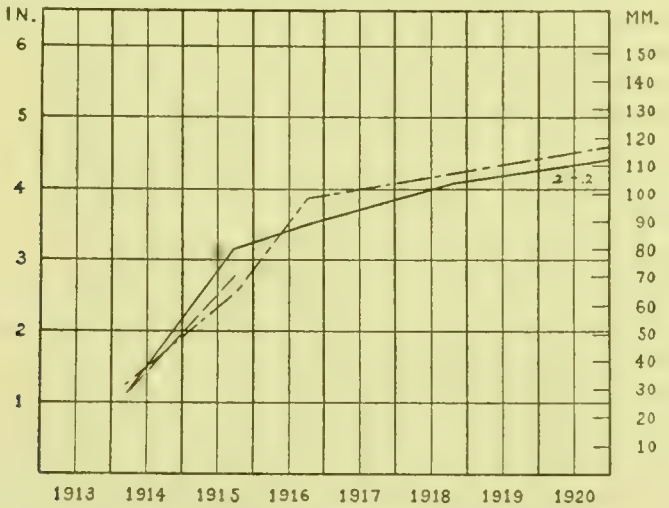

FIG. 83.—Growth of 1913 broods of original Carolina and Texas brood stocks. Egg production and hatch per female per year expressed, respectively, by figures on the curve. ————, Offspring of Carolina brood stock, selected for large size in the spring of 1914; — — — —, offspring of Texas brood stock, fed one winter; — — —, offspring of Texas brood stock, hibernated

study. These selected individuals at 6 years of age did not average 4½ inches, though, of course, there were some over 5 inches in length in the lot. Neither had they laid any eggs. There was, however, in the seventh year a small production of eggs and young in this stock. Their slowness of growth can not be well

accounted for. The severe winter of 1917–18 may have retarded their development somewhat, but the retardation in the average growth curve occurs before that winter. It seems only further evidence that selection of the large terrapins at the beginning of the second year does not necessarily mean that those terrapins will be the largest or best producers in the fifth or sixth year; that, as has been well shown in the 1912 "selects" and "runts," selection of brood stock as early as the second year is premature. The Texas brood of 1913 does not show normal growth. Its average growth has, however, been better than that of the Carolina brood which received the same treatment. No eggs have been laid by the Texas stock. It may be that the retarded average growth curve of the Texas stock is due to the fact that a number of the larger terrapins of this lot were lost in a heavy storm in the summer of 1918. This would also explain the late egg laying of this group.

1914 BROOD.

This lot of Carolina terrapins selected in the spring of 1915 from those terrapins that had been fed during the previous winter has not shown more than ordinary growth and did not produce eggs during 1919, the fifth year of its life. In 1920, the sixth year,

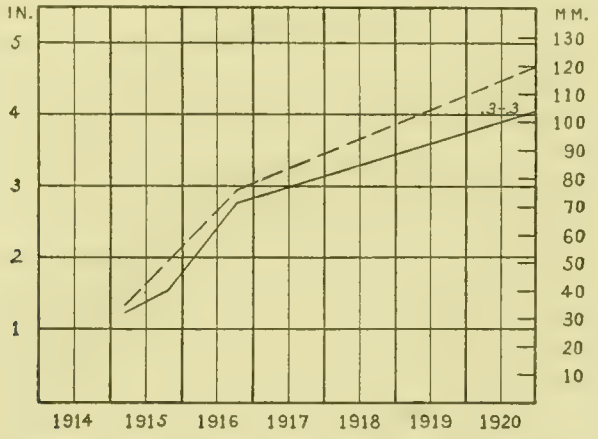

FIG. 84.—Growth of 1914 broods of original Carolina and Texas brood stocks. Egg production and hatch per female per year expressed, respectively, by figures on the curve. ———, Offspring of Carolina brood stock, selected for large size in the spring of 1915; — — —, offspring of Texas brood stock, selected for large size in the spring of 1915.

however, there was a small production of eggs. Early selection and the brood's later retardation in average growth, which has been evidenced in lots previously discussed, is further borne out here. The Texas brood of 1914 has been rather insignificant, inasmuch as it consisted of only five terrapins in 1919, the others having been shipped to Texas. These five averaged somewhat larger than the Carolinas of the same stock, but had not produced eggs up to 1920. To make room for other experimental lots they have been shipped to Texas to be liberated.

MORTALITY.

As has been pointed out in the report of 1917 mortality among adult terrapins is very small. It does not amount to more than one-half of 1 per cent. In the young the mortality runs higher, especially if the terrapins are winter-fed. The death rate

among young terrapins hibernating the first year after birth is, however, very small. There may be an increase during the year following, but it is negligible. The death rate in the nursery house, however, is a matter of importance, though in certain years it is small. The cause of heightened mortality in the winter-fed individuals is a disease, rather cancerous in nature, which attacks the head, flippers, and especially the tail of the terrapin. The disease rots off the tail and spreads to the body proper, probably affecting the spinal cord and causing paralysis and death. Often terrapins become blind or unable to eat because of the disease. Its cause is unknown, though it probably is due to a microorganism. The disease seems most virulent to those nursery boxes which are best heated or in the sun, while those which remain throughout the cold season in the shade or at a considerably lower temperature than the others do not suffer so high a death rate. The disease does not attack the weak and small terrapins alone, but often kills some of the best grown. The kind of food used seems to have no connection with the prevalence or the virulence of the disease. Antiseptic washes and thorough cleanliness in the house and boxes apparently have some advantages, but the disease will prevail even when the most scrupulous care is taken. Possible value of antiseptic treatments seems to be borne out to some extent in the table on page 110. Treatments have been with potassium permanganate solution applied to the nursery boxes at intervals of a day or every few days. The solution is poured into the boxes and thrown upon the sides, allowed to remain some time, and then drawn off. Early in the fall before young terrapins are housed a thorough treatment with formalin or copper sulphate solution is given the boxes and walls of the house. The floor, being sand, is treated with lime.

The first year that any antiseptic was used in the nursery house was 1915. In 1914 the percentage of mortality among terrapins housed for the winter was 29. In 1915, with the disinfecting treatments being used, the mortality dropped to 5 per cent. However, this drop in mortality rate may have been due to causes other than the use of the disinfectants, for since 1915 there has been a continued high mortality rate even though disinfectants have been used regularly.

Apparently the infecting organism can live in either salt, brackish, or fresh water, as the disease, once started, spreads when the water in the nursery boxes is changed from fresh to salt, or vice versa. Certain terrapins that are attacked recover after several weeks, but the majority die. What possibly is another symptom of the same disease, or perhaps another disease altogether, is the so-called "softening of the shell" among the young terrapins. It is found among the terrapins that make no growth and is due, perhaps, to faulty absorption of the yolk sac or to possible infection of the body wall during this process. Such infection could be readily conveyed to the internal organs and destroy the health of the terrapins so affected. The "softening of the shell" symptom is always accompanied by loss of the power of growth and sometimes by the loss of pigment in the carapace or by a deadened appearance of the entire shell. Terrapins that develop this latter symptom rarely live. The offspring of the Texas stock are as susceptible to the disease as those of the Carolina. Hybrids (Carolina–Texas cross) are none the less susceptible to the disease.

From a study of the winter-fed terrapins during the winter of 1919–20, it is suggested that high temperature and direct sunlight on the nursery boxes in which are held the several lots of yearlings are correlated closely with the prevalence of the disease. It appears that the greatest mortality occurred in those boxes closest to the stove and

in such locations in the nursery house that direct sunlight fell upon them. Greatest growth also occurs in those terrapins held closest to the heater, and therefore there appears to be a direct relation between rapid growth and increased prevalence of the disease. The mortality of winter-fed terrapins, as it has occurred during the period from November of one year to March of the next since 1912, is as follows:

MORTALITY OF WINTER-FED TERRAPINS.

Year.	Number fed.	Mortality.		Year.	Number fed.	Mortality.	
		Number.	Per cent.			Number.	Per cent.
1912	546	40	7	1916	2,126	227	10
1913	569	41	7	1917	2,038	554	27
1914	1,771	522	29	1918	(a)		
1915	1,493	87	5	1919	2 937	529	18

a All terrapins of the 1918 brood were liberated.

SUMMARY.

The egg production and the hatch of the original and second Carolina and of the Texas brood stocks during their captivity at Beaufort have been reviewed. It appears that the probable average age of individuals of the two Carolina brood stocks in 1921 is 28+ and 18+ years, respectively. Egg production in domestic terrapins has occurred as early as the fourth year. In terrapins fed one or two winters egg production generally begins in the fifth or sixth year. In hibernating terrapins it rarely occurs before the seventh year. Egg production immediately after penning is small but increases to normal in about the third year of captivity. At least for the first six years of sexual maturity, probably for much longer, it is greater among the fed terrapins of a certain brood than among those of the same brood allowed to hibernate. It is estimated that maximum egg production occurs when a terrapin is approximately 25 years of age.

Terrapins in captivity have been observed to lay as often as five times in a single season. Average annual egg productions as high as 23.6 and 24.5 per female have been recorded for the original Carolina stock and the Texas brood stock, respectively. The maximum average annual egg production of any female under observation has been 35 eggs; the maximum hatch per female, 31.2 young. This record was obtained in 1920 from the 1909 offspring of the "wild" stock.

Rats, because of their burrowing into lately made nests and destroying large numbers of eggs, are serious enemies of the terrapin.

The proper numerical relation of males to females for maximum fertility is not known exactly, and it is difficult to ascertain it accurately in view of the habit of promiscuous mating among terrapins. One mating, moreover, may give rise to fertile eggs for four years thereafter; that is to say, the life of the spermatozoon in the female after copulation may be at least four years. A 90 per cent hatch, which appears to be normal, can, however, be obtained among well-matured terrapins when the number of males is one-third the number of females. This average percentage of hatch is not increased by the presence of a larger proportion of males. It appears from the study of certain of the domestic broods that while egg laying is small a maximum fertility may

be obtained, but not always, from broods in which there are 5 to 12 males per 100 females. However, when egg production is substantially increased it appears that there must be more males to obtain maximum fertility. Broods in which the males numbered 24 to 32, respectively, per 100 females produced a normal fertility, even though egg production was large. It seems warranted, then, to conclude that from 24 to 32 males per 100 females are necessary in order to obtain a 90 per cent fertility when the females of a brood average perhaps from 12 to 24 eggs per season. Males are apparently a year slower than the females of the same brood in coming to sexual maturity.

The growth of terrapins from birth to their maturity is recorded. The increasing number and percentage of individuals of a given brood reaching the 5 and 6 inch lengths, the marketable size of terrapins, as age increases has been pointed out. In the sixth year 60 per cent of a given winter-fed lot reached the 5-inch length and 6 per cent the 6-inch length. In the seventh year of a given hibernated lot 57 per cent of the brood reached the 5-inch length and 1 per cent the 6-inch length.

A large number of each brood of winter-fed terrapins will have reached the 5-inch length by the fourth year. In the fifth year the average winter-fed terrapin will pass the 5-inch mark. Winter feeding not only hastens growth but quickens development of the sex organs and influences toward greater fecundity at an earlier date than occurs among terrapins allowed to hibernate. Offspring of domestic terrapins appear to do as well in captivity as the offspring of "wild" stock. The maximum growth for any terrapin raised in captivity under observation has been 81 mm. for one year's and 104 mm. for two years' development. Small terrapins seem to make faster growth when fed oysters than they do when fed salt or fresh fish. Adults make good growth when fed fresh fish.

Selection of brood stock should not occur before the third year, preferably later. Selection for this purpose should be of the largest individuals of a brood, since there is a positive correlation between size, age, and fecundity. Earlier selection than in the third year is undesirable, since rapid-growing 1 and 2 year old terrapins often have their growth retarded in the following years and at the fifth year are no larger and no more productive than those terrapins which were poorly grown in the first two years.

It appears that the more space allowed terrapins in captivity the greater will be their growth within certain limits. Plenty of space may also have a bearing in its possible influence on increased egg production.

Mortality among yearling terrapins fed in a warmed nursery house during the winter varied from 7 to 29 per cent from 1912 to 1919. Mortality among the adult terrapins, as has been pointed out in another publication, is about one-half of 1 per cent. There is no doubt that many more than one-half of the young terrapins of any brood will live in captivity to attain a salable size. Yearling Texas and Carolina terrapins and the hybrids of these stocks seem to be equally susceptible to a disease, probably bacterial, which has killed many young terrapins in the nursery house at Beaufort. Disinfecting treatments of the nursery house and boxes have not proved to be a consistent control of the disease.